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GIFFORD PINCHOT, Forester.

THE PRESERVATIVE TREATMENT OF LOBLOLLY PINE CROSS-ARMS.

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INTRODUCTION.

THE DEFICIENCIES OF THE PRESENT METHOD.

All who are familiar with wood preservation know that the ease with which the preservative can be injected depends upon the character and condition of the wood. Porous species, such as red oak and certain pines, absorb the liquid more readily than such dense woods as tamarack and hemlock. In a single species, timber cut from open-grained fast-grown trees takes treatment more readily than that from trees which grow slowly, with a consequent close grain; porous sapwood receives the liquid more readily than the denser heartwood, the pores of which are more or less filled with oils and other infiltrated organic substances; and wood is easier to treat when dry than when a large amount of water in the cells presents a mechanical resistance to the entrance of the preservative. In small timbers, which receive an absolute penetration, the difference in absorption is more apparent than in the treatment of large dimension stuff, merely the outer layers of which are impregnated.

The cross arms manufactured throughout the South are cut mainly from rapidly grown, open-grained loblolly pine. No distinction is made as to species, however, and shortleaf and longleaf are frequently included. At present cross arms cut from various parts of the tree are mixed indiscriminately; hence cross arms cut from heartwood are treated with those cut from sapwood, and those which have reached an air-dry condition with freshly cut or rafted material. As a consequence, the amount of the preservative forced into the wood varies greatly; the dry sapwood material receives more than is required and the heartwood not enough.

PRELIMINARY TESTS.

These considerations induced the Forest Service, in February, 1903, working in cooperation with the American Telephone and Telegraph Company and the Norfolk Creosoting Company, to make a series of

six experimental runs at the latter company's plant near Norfolk, Va. The principal objects of this test were to demonstrate the inequality of the treatments received by different classes of material and to furnish a basis for more detailed work in the future, with a view to rendering the treatments more uniform and economical.

For creosoting under pressure, the timber is piled in small trucks or buggies, hauled into large, air-tight horizontal cylinders, and the doors tightly closed. Live steam is then admitted for varying lengths of time, usually for from three to six hours, according to the character and dryness of the wood. The steam is then expelled and a vacuum drawn for several hours to exhaust the air and water remaining in the wood cells. Creosote (dead oil of coal tar) is then allowed to run into the cylinder from one of the storage tanks. When the oil appears in the overflow pipe, indicating that the cylinder is full, force pumps are started, and the resulting pressure is maintained in the cylinder until the desired amount of oil per cubic foot of timber has been forced in. This amount has previously been calculated for the entire load, and when the indicator on the storage tank shows that the required amount of oil has been drawn from the tank the supply is shut off, and that which remains in the cylinder is forced back into the storage tank. The treated load is left to drip in the cylinder for a short time, and is then hauled out and unloaded.

GRADING THE ARMS.

Before the treatment was begun 14,000 arms were separated into three classes, in accordance with the relative amounts of heartwood and sapwood each arm contained. Class A was composed of arms with 75 per cent or more of heartwood; Class B, 75 per cent or more of sapwood; and Class C contained less than 75 per cent of either heartwood or sapwood. No attempt was made to separate the arms according to the amount of moisture they contained, hence nearly green and partially air-dry arms were represented in the same class. Six runs were made in these preliminary experiments. In order to ascertain the exact absorption of oil, a number of arms of each class were weighed before treating and so marked that they could readily be identified and weighed after the treatments were finished. A record of the runs is given in Table 1.

RECORD OF PRELIMINARY RUNS.

TABLE 1.—*Record of the preliminary tests.*

Load.	Class.	Period of treatment.			Oil pressure.	Absorption per cubic foot.		
		In steam.	In vacuum.	In oil.		Average.	Maximum.	Minimum.
		Hours.	*Hours.*	*Minutes.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
1	Mixed partly seasoned.	4	5	45	22	S. 17.63 H.& S. 9.30 H. 4.76	S. 26.92 H.& S. 20.88 H. 10.99	S. 7.14 H. & S. 1.65 H. 1.65
2	Sap partly seasoned.	None.	2	31	25	15.02	25.82	7.14
3	.....do.....	3	4	12	29	17.08	35.71	6.04
4	Mixed green.....	6	5	55	50	S. 9.98 H.& S. 8.40 H. 7.45	S. 15.38 H.& S. 13.19 H. 12.64	S. 6.59 H. & S. 3.85 H. 3.30
5	Heart partly seasoned.	3	4	160	80	10.30	23.08	2.75
6	Heart and sap partly seasoned.	4	4	50	36	12.07	26.37	2.75

Load No. 1 was made up in accordance with specifications which may be taken fairly to represent ordinary commercial practice. No attempt was made to restrict the load to any one class of arms, but, on the contrary, all three classes were represented; and care was taken to make the load as nearly as possible representative of the usual conditions for treatment. The preliminary steaming of four hours was at about 20 pounds pressure to the square inch. Twelve pounds of creosote to the cubic foot was required. In the same load the variation in the absorption of oil was in some cases from nearly 27 pounds per cubic foot, the maximum for the sap class, to about 1½ pounds, the minimum for the heart class; a total difference of over 25 pounds per cubic foot. The average absorption per cubic foot for the sap class exceeded the specified amount by about 5½ pounds, whereas that of the heart class was over 7 pounds too light. Even the maximum amount absorbed by any one heart arm was 1 pound less than the specifications called for. The sap class absorbed nearly twice as much oil as the mixed class and 3.7 times as much as the heart arms.

Load No. 2 was made up of partially seasoned arms. The customary steam bath was omitted, and the wood was warmed merely by passing superheated steam for thirty minutes through the coils in the bottom of the cylinder. The absorption of this load averaged more than 3 pounds per cubic foot in addition to the amount required by the specifications.

Load No. 3 was made up of material similar to that in load No. 2. It was given a bath of live steam for three hours. The steam was then blown off and the temperature maintained for one hour by the superheated steam in the coils. A four-hour vacuum was drawn before the oil pressure was applied. The absorption of this load averaged over 5 pounds per cubic foot more than the specifications require.

It should be noted that the time required for this load (treated according to the regular specifications) was eight hours and twelve minutes, whereas load No. 2 required only two hours and thirty-one minutes.

Load No. 4 was composed of arms representing all three classes. The preliminary treatment consisted of six hours steam, one hour blow-off, and five hours vacuum. That the wood absorbed the oil comparatively slowly is shown by the fact that a pressure for fifty-five minutes at 50 pounds was required to force the desired amount of oil into the wood. By reference to the table it will be noted that the variation in the amount of oil absorbed by the several grades in this load is comparatively slight. This may be due to the fact that live steam has a greater influence upon green heartwood than upon heartwood partially seasoned. On the other hand, sapwood becomes more receptive of oil when air seasoned than when subjected to the bath of live steam.

Load No. 5 was composed of partially seasoned heart arms. The wood absorbed the oil very slowly and showed the difficulty of forcing large quantities of oil into the dense heartwood. Twenty-four per cent of the total amount of oil absorbed during the entire treatment was taken up by the wood within fifteen minutes after the oil was first turned in and before the pumps were started. It required nearly ten times as long to force the remaining 76 per cent of oil into the wood as it did for the wood to absorb without pressure the 24 per cent. The average absorption was 10.3 pounds per cubic foot, as compared with 4.76 pounds for the heart arms in load No. 1, in which the arms of the three classes were mixed indiscriminately.

Load No. 6 was made up of partially seasoned heart and sap arms (Class C). The average absorption was 12.07 pounds per cubic foot. The variation between the minimum and maximum absorption per cubic foot was due to the fact that in some arms the percentage of heartwood largely exceeded that of the sapwood, and vice versa. It is therefore evident that the maximum amount was absorbed by an arm having a large percentage of porous sapwood, while the minimum amount was taken by an arm in which the heartwood predominated.

These preliminary tests, although necessarily incomplete, served to bring out strongly several important points: They clearly demonstrated that the present system of treating heart arms and sap arms together, without regard to the amount of moisture they contain, results in an excessive and detrimental absorption of oil by the sapwood and an insufficient penetration of the heartwood; that a lighter treatment than 12 pounds of oil to the cubic foot is probably sufficient for sapwood; that an economy could be effected by regulating

more carefully the preliminary steam and vacuum processes; and that allowing the material to become air dry before treatment is beneficial.

PLANS FOR THE FINAL TESTS.

After the undesirable results of the prevailing method had been demonstrated it was necessary to devise methods of handling and treating the material which would result in a more thorough, more uniform, and less expensive penetration. In cooperation with the American Telephone and Telegraph Company an extended experiment was begun in August, 1905, at the plant of the Norfolk Creosoting Company. Arrangements were made by which 1,200 freshly cut cross arms were to be turned over to a representative of the Forest Service each month for a year. These arms were cut in Montgomery County, N. C., about 300 miles from Norfolk. On their arrival at the creosoting plant the arms were graded into three classes, similar to those which had been adopted in the preliminary treatments. The arms were weighed as soon as they were removed from the car, and piled in various forms to season. A portion of each class was soaked in water for ten, twenty, and thirty day periods before piling. It was at first thought that the loss in weight en route from the sawmill to Norfolk might be so great as not to permit the weight at Norfolk to be considered as the green weight of the wood. To test this probable loss an agent of the Forest Service was sent to the mill to weigh the first month's cut, just as the arms came from the saw. The arms were then shipped in a closed car and reweighed in Norfolk immediately as they were removed from the car. As the average loss in weight was only a fraction of a pound, it was too slight to be taken into consideration. Arrangements were made with the sawyer in North Carolina to use only absolutely green material for subsequent shipments of experimental arms, and with the railroad companies to rush the cars through without delays.

SEASONING.

THE AIR-DRY AND OVEN-DRY WEIGHTS OF LOBLOLLY PINE.

Timber is ordinarily said to be air-dry when its moisture content is constant on more or less direct exposure to the open air. The term is merely relative. Wood exposed to the full force of a summer sun during several weeks of dry weather obviously will contain less moisture than the same wood under more humid conditions. In extreme cases this variation may be several pounds per cubic foot of timber, but ordinarily it is confined within comparatively narrow limits. Hence the term " air-dry " furnishes a convenient means for distinguishing the moisture content from that of green, kiln-dry, steamed, and oven-dry wood.

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All of these terms are relative except the last or oven-dry weight. Hence this has been adopted as a basis for determining the amount of moisture present in loblolly pine of different weights. The oven-dry weight is obtained by extracting all possible moisture from the wood at a temperature of 100° C. A small amount of water still remains even at this temperature, and can only be eliminated by the destruction of the wood itself. However, for all practical purposes, the oven-dry weight may also be considered the absolutely dry weight.

For the heart class of loblolly pine cross-arms this weight was found to be 28.8 pounds per cubic foot. A cubic foot of the sap class weighed 27.8 pounds, and the intermediate class weighed 28.1 pounds per cubic foot. For practical purposes these weights are similar enough to be considered identical; so the weight of the intermediate class, 28.1 pounds per cubic foot, was applied to the other two classes. The practical application of the figures thus becomes much simpler because it is not necessary to take into consideration the proportionate amounts of heartwood and sapwood. The similarity of the oven-dry weights of heartwood and sapwood indicates that the greater weight of air-dry heartwood is due almost wholly to a greater moisture content, and not, as is popularly supposed, to the added weight of the resins, gums, and other substances which are deposited in the cells during the change of the wood from sapwood to heartwood.

Table 2 gives the weight of the moisture and the moisture content in per cent of the dry weight of loblolly pine at different stages of seasoning. If the weight of a particular stick of timber and its volume are known its moisture content can be immediately determined.

TABLE 2.—*Weight of wood of loblolly pine at different stages of seasoning.*

Weight per cubic foot.	Weight per arm (0.91 cubic foot).	Amount of moisture per cubic foot.[a]	Moisture content in per cent of oven-dry weight.	Weight per cubic foot.	Weight per arm (0.91 cubic foot).	Amount of moisture per cubic foot.[a]	Moisture content in per cent of oven-dry weight.
Pounds.	*Pounds.*	*Pounds.*	*Per cent.*	*Pounds.*	*Pounds.*	*Pounds.*	*Per cent.*
60	54.6	31.9	113.5	44	40.0	15.9	56.6
59	53.7	30.9	110.0	43	39.1	14.9	53.0
58	52.8	29.9	106.4	42	38.2	13.9	49.5
57	51.9	28.9	102.8	41	37.3	12.9	45.9
56	51.0	27.9	99.3	40	36.4	11.9	42.3
55	50.1	26.9	95.7	39	35.5	10.9	38.8
54	49.1	25.9	92.2	38	34.6	9.9	35.2
53	48.2	24.9	88.6	37	33.7	8.9	31.7
52	47.3	23.9	85.1	36	32.8	7.9	28.1
51	46.4	22.9	81.5	35	31.9	6.9	24.6
50	45.5	21.9	77.9	34	30.9	5.9	21.0
49	44.6	20.9	74.4	33	30.0	4.9	17.4
48	43.7	19.9	70.8	32	29.1	3.9	13.9
47	42.8	18.9	67.3	31	28.2	2.9	10.3
46	41.9	17.9	63.7	30	27.3	1.9	6.8
45	41.0	16.9	60.2				

[a] The total weight per cubic foot less the oven-dry weight (28.1 pounds).

Loblolly pine cross-arms present unusually favorable conditions for rapid seasoning. The wood is open-grained and porous; the percentage of sapwood is high; the cross-arms are of comparatively small dimensions (3¼ by 4¼ inches by 10 feet), and the percentage of exposed surface is relatively large. The pin and bolt holes bored at right angles to the fibers increase the exposed cross-section area and probably have an important influence on the rate of evaporation. Therefore the results that have been derived can not be applied without modification to timber of other dimensions even of the same species.

In Europe the regular practice is to permit the timber to become air-dry before treatment; but in America it is a common statement that when a large contract is given for treated timber the trees which will furnish the wood are still standing in the forests. Hence, even where the value of air seasoning is recognized, the questions of most pressing importance are, "How long must the timber be held before it is in a condition to treat, and how can this period be lessened?"

The length of time required for air seasoning depends upon the character of the timber, atmospheric conditions, and the manner in which it is piled. Each of these points will be considered in turn.

CHARACTER OF THE TIMBER.

The character of the timber includes such considerations as the physiological condition of the wood at the different seasons of the year, whether the timber is composed of heartwood or sapwood, and like questions. These, however, are of practical importance only in so far as they affect the length of the seasoning period. It is interesting to note that timber cut in the fall weighs least,[a] and that cut in the winter is heaviest; that of the spring and summer months occupies an intermediate position. This is true in cross-arms of all three grades, as is shown in Table 3.

TABLE 3.—*Green weight of loblolly pine according to season when cut.*

Portion of tree.	Weight per cubic foot.			
	Autumn.	Spring.	Summer.	Winter.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*
Heartwood	42.4	42.6	45.1	45.5
Intermediate	48.8	49.9	50.2	51.1
Sapwood	55.6	57.4	57.4	58.2

[a] See Forest Service Circular 103, Seasoning of Telephone and Telegraph Poles, pp. 13 and 14, for further corroboration of this fact.

Far more marked than the seasonal differences of the wood, and of much greater practical importance, are the differences between heartwood and sapwood. It will be seen that sapwood arms cut in the spring weigh nearly 15 pounds more per cubic foot than heartwood arms cut in the same season. The classes differ not only in green

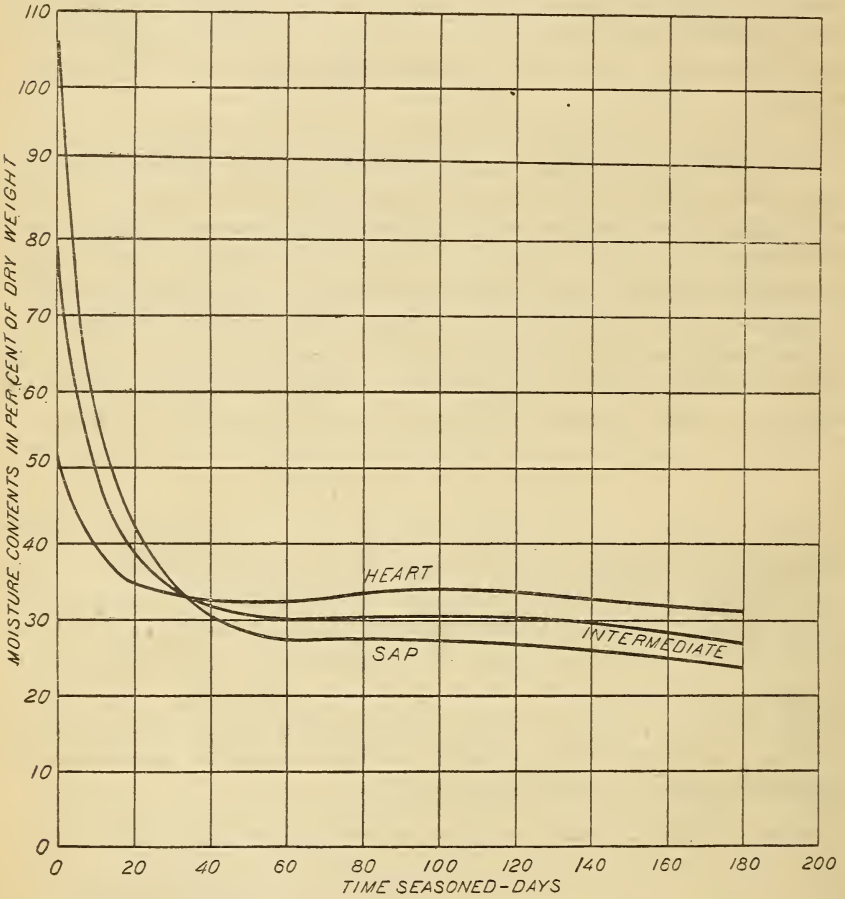

FIG. 1.—Comparative rates of seasoning of cross-arms composed of varying amounts of heartwood and sapwood.

weight but in the rate at which the moisture evaporates. This is strikingly shown in Table 4 and in figure 1. These show the behavior of spring-cut arms of all three classes piled in the same way under similar conditions.

TABLE 4.—*Comparative rates of seasoning of loblolly pine heartwood, sapwood, and intermediate cross-arms.*

Days seasoned.	Heartwood.			Sapwood.			Intermediate.		
	Weight per arm.	Weight per cubic foot.	Moisture content.	Weight per arm.	Weight per cubic foot.	Moisture content.	Weight per arm.	Weight per cubic foot.	Moisture content.
	Pounds.	*Pounds.*	*Per cent.*	*Pounds.*	*Pounds.*	*Per cent.*	*Pounds.*	*Pounds.*	*Per cent.*
0	38.8	42.6	51.5	52.7	57.9	105.8	45.8	50.3	79.0
30	34.2	37.6	33.4	34.5	37.9	34.8	34.3	37.7	34.0
60	33.9	37.3	32.5	32.6	35.8	27.2	33.3	36.6	30.0
90	34.3	37.3	33.8	32.6	35.8	27.3	33.4	36.7	30.3
120	34.2	37.6	33.7	32.5	35.7	26.9	33.4	36.7	30.3
150	33.9	37.3	32.3	32.1	35.3	25.4	33.0	36.3	29.0
180	33.6	36.9	31.2	31.6	34.7	23.6	32.5	35.7	26.9

At the outset the sap arms had a moisture content of 105.8 per cent, in comparison with 51.5 per cent for the heart arms. In thirty days the moisture content of the sap class had been reduced to 34.8 per cent, a loss of 71 per cent, while the heart arms, whose weight at this time differed from that of the sap arms by only a fraction of a pound, had lost only 18.1 per cent. By the thirty-fourth day the arms of all three classes showed the same moisture content. The heart arms had lost practically all the moisture that can be evaporated in seasoning periods of ordinary length, while the sap arms steadily continued to decrease in weight for about six weeks, when the rate of evaporation rapidly declined. The arms of the third class occupied an intermediate position throughout.

ATMOSPHERIC CONDITIONS.

The most favorable atmospheric conditions for seasoning are high temperature, accompanied by low humidity and sufficient wind to promote a constant circulation of air around the timber. Throughout the greater portion of the United States these conditions are most nearly approached during the summer months, while winter is least favorable for seasoning. Hence timber cut in the spring receives the full benefits of the summer weather, and consequently attains an air-dry condition in less time than that cut in any other season. Under favorable weather conditions, loosely piled cross-arms will often attain an approximately air-dry weight in five or six weeks. Summer-cut timber, which must season in the fall, and timber cut in the winter for spring seasoning, require somewhat longer periods, while the seasoning of the autumn-cut timber, coming as it does in the midst of the winter, is the slowest of all.

MANNER OF PILING.

In addition to natural factors, another of hardly less importance is introduced in the manner of piling the timber. In general commercial practice, economy of space and handling are rightly con-

sidered of the first importance, and all other considerations are made subservient. Present practice does not secure the best results, but if there were no means by which these could be attained without the sacrifice of labor and of space economy no change in the present pile forms would be recommended. However, the adoption of proper methods does not appreciably increase either labor or space.

SPACING.

In most seasoning yards the arms are piled closely together, there being about 28 on each tier. (Fig. 2.) In some cases, however, a partial improvement is made by changing the position of either one arm or two arms at the center and ends of the tiers, as is shown in

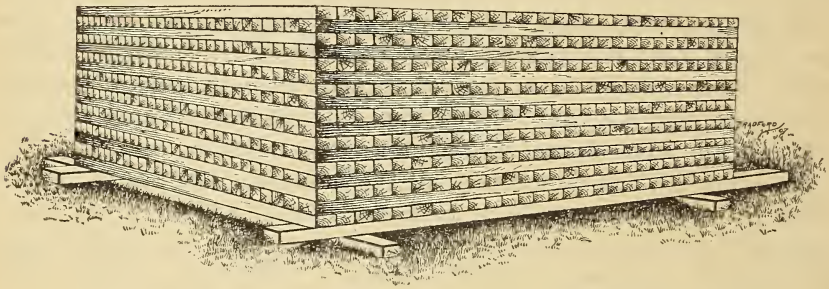

FIG. 2.—Common method of piling cross-arms in commercial practice.

figure 3. Both of these pile forms retard the evaporation of the moisture from the wood. In the closest pile the circulation of air is almost entirely shut off, and all evaporation must take place from the ends of the timbers. In case of heavy rain or melting snow the

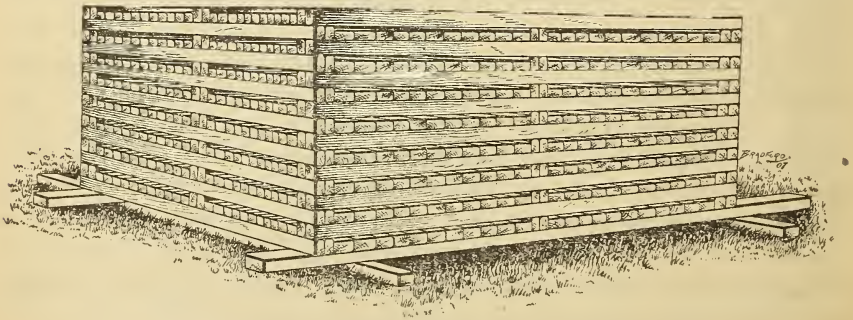

FIG. 3.—Modified form of piling cross-arms in commercial practice.

water trickles down over the timber, and the dampness thus promoted, together with even moderate temperatures, stimulates the growth of fungi, while the close contact of the timbers permits a rapid spread of infection.

It often happens, therefore, that where timber is so piled the growth of wood-destroying fungi has reached a serious stage before the timber itself has attained its air-dry condition; hence it is not uncommon to hear the assertion that the sapwood of loblolly pine will rot before it can become air-dry. Such an assertion is probably untrue in every case; and it is certain that loblolly, or any other timber, in a form so well adapted for rapid evaporation of moisture as cross-arms, can be fully seasoned in any part of the country without risk of deterioration during the seasoning period. By adopting the pile form shown in figure 3 a circulation of air is permitted along the sides of the arms. The upper and lower faces are still so closely crowded together that no air currents can pass between them. Obviously, the next step is to separate the arms from each other by a space of sufficient size to insure a thorough circulation of the air on all sides of the arms, and yet not so large as to consume unnecessary space. When these two requirements are met, the ideal form of pile is attained.

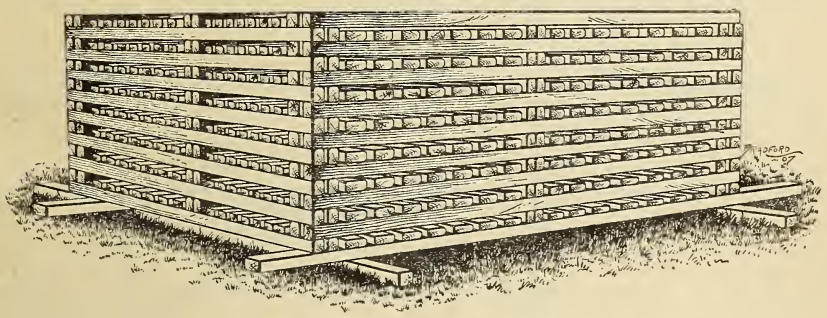

FIG. 4.—Ideal form of piling cross-arms, 20 by 20, giving free circulation of air.

Many experiments have shown that if from 20 to 22 arms are allowed to each tier, and arranged as shown in figure 4, most of the desired results will be attained. This pile, called for convenience the 20 by 20 form, compared with those in general use, gives a surprising difference in the rate of seasoning, as shown in figure 5. For example, sap arms of the July allotment were piled as in figures 4 and 3. Those in the 20 by 20 pile dried out to a weight of 34.1 pounds per arm in a little more than six weeks, while more than sixteen weeks elapsed before a like weight was reached by the arms in the figure 3 or 28 by 28 pile. The only difference in the two piles was in the number of arms to the tier. Had the arms in the 28 by 28 pile been packed closely together, as in figure 2, the difference in the rate of seasoning would have been much greater.

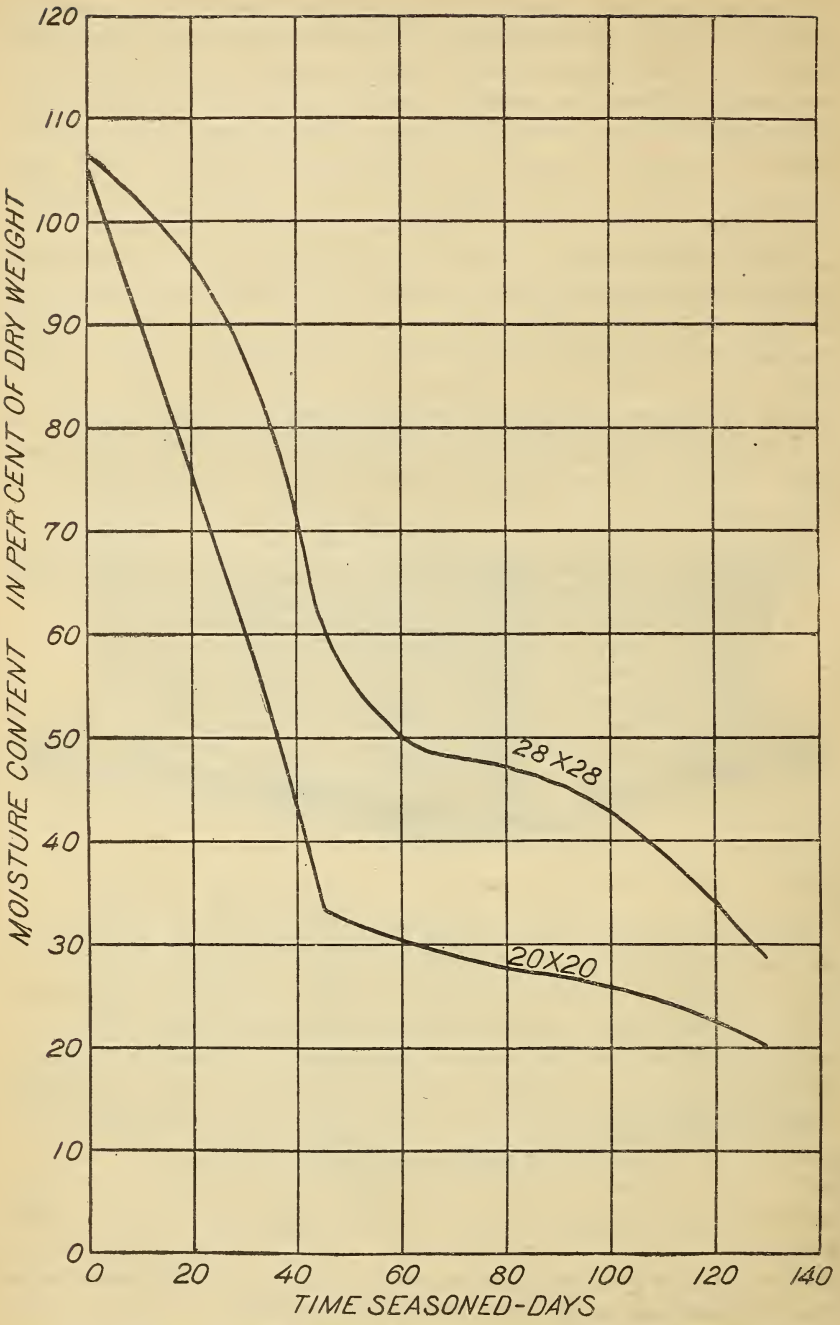

FIG. 5.—Comparative rates of seasoning of cross-arms piled 28 by 28 and 20 by 20. [Cir. 151]

Under climatic conditions such as prevail in most parts of the United States throughout the greater portion of the year it is best

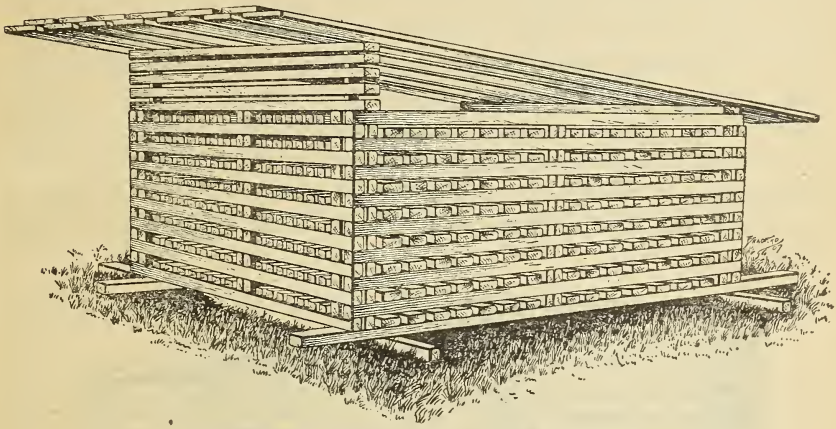

FIG. 6.—Recommended method of roofing cross-arm piles with boards.

to expose the timber directly to the sun and rain. During the winter months, however, or whenever there is a prevalence of rain or snow,

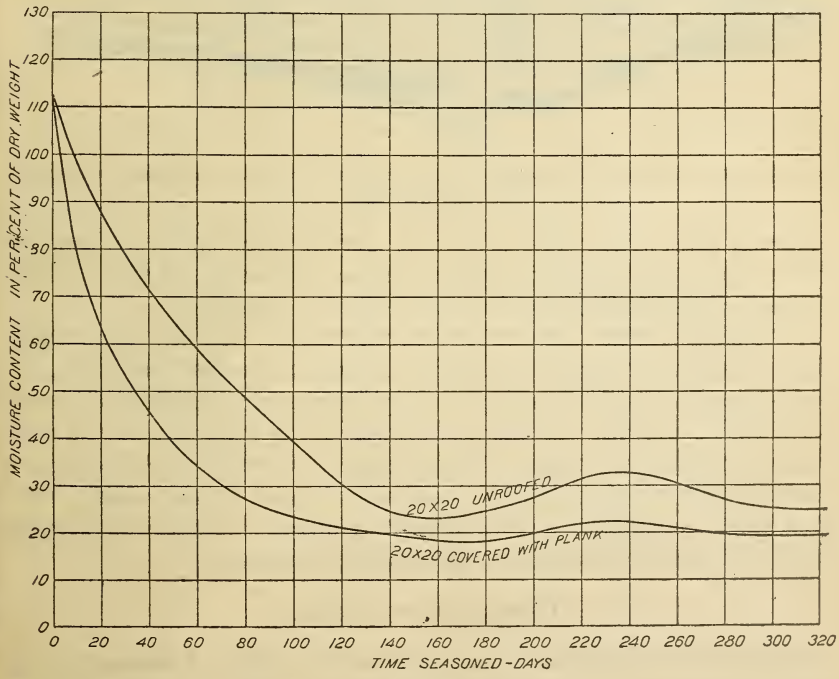

FIG. 7.—Rates of seasoning of winter-cut cross-arms piled 20 by 20, with and without board roofs.

excellent results will be secured by piling the arms under a roof, without walls, or by constructing a rude roof over each pile. This latter method will probably be the cheapest, as it avoids the difficulty of handling the arms in a confined space. If the boards are placed as shown in figure 6, the arms below will remain dry during even a heavy rain or snow storm. Of the two, snow is the more serious, since it generally takes longer to evaporate; and during its slow melting the partially seasoned timber will absorb moisture without giving it off. In all cases the roofing should extend out over the pile on all sides to protect the ends of the arms, for it is there that the evaporation or absorption of moisture is most rapid. The effect of a roof over the piles during a rainy period is strikingly shown in the curves in figure 7.

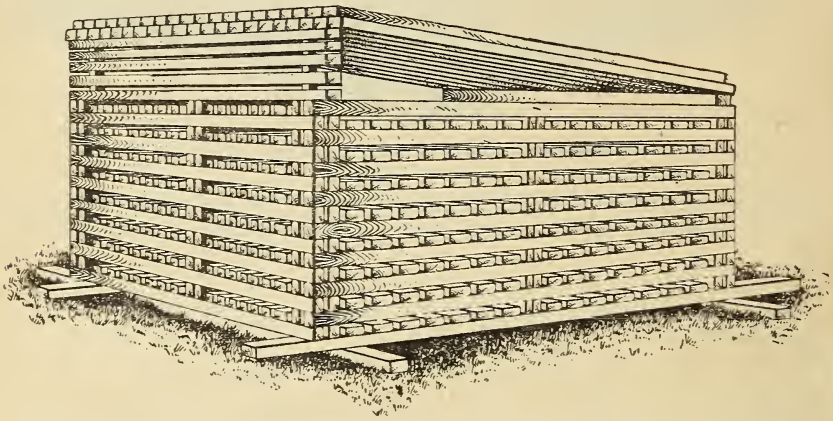

FIG. 8.—A 20 by 20 pile of cross-arms with a roof constructed of the arms themselves—not recommended.

During the winter the difference between the moisture content of the roofed and unroofed piles became constantly greater; it was not until spring that the two curves began to converge.

It is not advisable to attempt to form the roof with the arms themselves, as shown in figure 8, for three reasons: In the first place, the roof is too short and too narrow to give proper protection to the ends and sides of the pile; in the second place, the exposure of the roof arms to maximum changes of atmospheric condition causes severe checking and warping, with a consequent loss of timber; and, in the third place, considerably more labor is required to handle the greater number of pieces necessary in constructing the roof.

IMMERSION IN WATER.

Exhaustive experiments were made on the effect of water soaking before seasoning. It was found that there was little to be gained by

immersion for different periods up to thirty days. The general results are shown in figure 9.

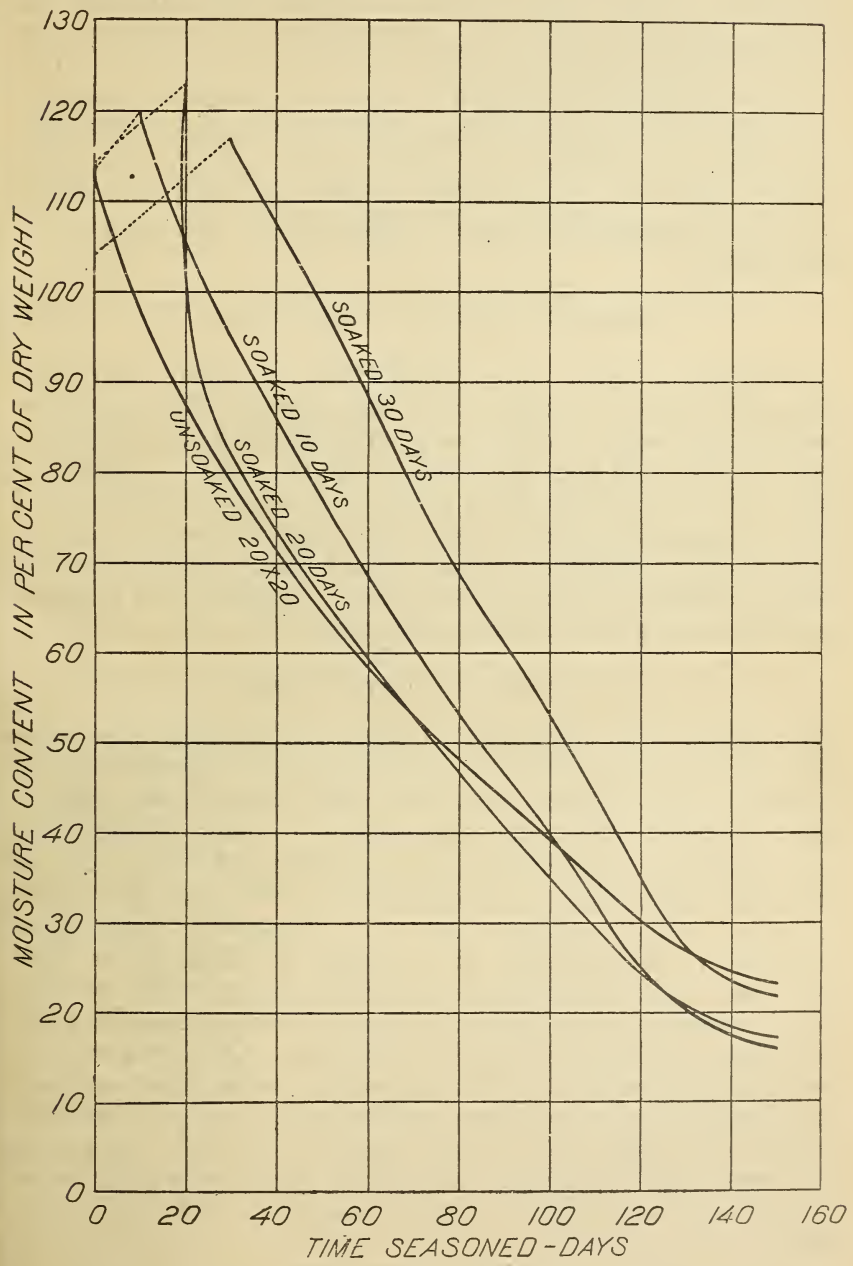

FIG. 9.—Comparative rates of seasoning of soaked and unsoaked cross-arms.

However, it should be remembered that in these experiments the longest period of immersion was one month, since it was not believed

that the beneficial effect of soaking could be such as to warrant longer immersion. Had the arms been soaked for several months it is possible that wholly different results would have been obtained. So far as the present purpose is concerned, however, such results would have been of little practical value.

It may therefore be concluded that immersion before seasoning is not justified if it involves additional time and expense. The beneficial effects on subsequent seasoning, except, possibly, where the soaking is continued for prolonged periods, are slight; and soaked arms do not appreciably surpass unsoaked ones in the absorption of preservative.

SHRINKING, CHECKING, AND WARPING.

Shrinking, checking, and warping, which commonly take place during the seasoning of timber, are due to variations in the moisture content of the wood. A cubic foot of green sapwood of loblolly pine, weighing about 60 pounds, contains approximately 32 pounds of water. In the seasoning of the timber to an air-dry condition, to a weight of, say, 34.5 pounds per cubic foot, about 25.5 pounds of water are evaporated. This great change in the moisture content manifests itself by reducing the bulk of the timber. Generally this is accompanied by more or less checking and warping.

THEIR EFFECTS ON INSULATOR-PIN HOLES.

In Bulletin 70 of the Forest Service[a] it is explained that water may exist in wood in two states, either as imbibed moisture, which is absorbed by the cell walls, or as free water, which merely fills the pores or cavities of the wood like honey in a comb. In wet and in green wood the water exists in both conditions. In the process of seasoning the free water is evaporated before the amount of moisture in the cell walls is reduced, and as its evaporation brings about no change in the substance of the wood, no shrinkage or other effect takes place. According to one theory the cell walls are made up of exceedingly minute particles of material called mycellæ, which are invisible even by the aid of a microscope. When comparatively dry wood is subjected to moisture the water readily passes into these mycellæ and forces the particles farther apart, causing a consequent increase in the bulk of the wood. Similarly, when the evaporation of the free water is complete, the moisture begins to be drawn from the cell walls, the particles are drawn together, and shrinkage takes place.

[a] Effect of Moisture on the Strength and Stiffness of Wood, Tiemann.

To determine whether the shrinkage in the cross-arms during air seasoning is sufficient to reduce appreciably the diameter of the holes for the insulator pins, measurements were made on several hundred arms of the heart, sap, and intermediate classes. It was found that for all practical purposes this shrinkage can be disregarded.

The objection to air seasoning is sometimes made that, although the area of the holes is not materially reduced, the shape is so distorted as to prevent the ready entrance of the pin. Theoretically, there is some basis for this fear, as shrinkage across the grain is much greater than longitudinally, and hence there might be a tendency for the holes to assume an elliptical shape. Close observation, however, failed to show that this possibility need be considered in practice.

TREATING.

The object of the experiments in the treatment of the cross-arms was to devise a process which would insure a uniform, efficient, and cheap impregnation. The preliminary work had shown that under the system in common use the sap-wood portions of the arms received an excess of oil; this not only added to the cost of treatment but proved an actual detriment, because the oil exuded in warm weather and dripped upon passers-by. On the other hand, the heartwood portions of the arms received a merely superficial penetration. It is true that heartwood is naturally more durable than sapwood, yet this natural durability is by no means equal to that of sapwood thoroughly impregnated with a good preservative. This is especially true in such species as loblolly pine, because the heartwood is by no means durable. As the surface of most of the arms is composed of both heartwood and sapwood, it is apparent that both classes of wood should be thoroughly preserved. The decay of the heartwood portion, no matter how small, in most cases renders the entire arm unfit for service.

In the preliminary treatments it was shown that the preservative is absorbed much more readily into the sapwood portions than into the heartwood, and that the application of pressure is necessary to force the preservative into the more impervious heartwood. This pressure may be applied by force pumps, as in the closed-cylinder processes, or by the atmosphere, as in the open-tank method. In either case the sapwood is thoroughly saturated with the preservative before the heartwood has received more than a superficial painting. In order to obtain a uniform penetration, without excess of oil, it is necessary to continue the pressure until the heartwood has received the desired penetration, and then to extract and recover the superfluous oil from the treated wood. The finding of a method to do this constituted the principal object of the experiments. The first series

of experiments was undertaken to secure the desired penetration. The extraction of the superfluous oil constituted the object of the latter tests.

EFFECT OF THE PRELIMINARY PROCESSES OF LIVE STEAM AND VACUUM.

The preliminary bath of live steam, which is commonly applied in the treating plants of this country, is undesirable from several points of view. It is expensive; it adds from three to six hours to the length of the treatment; and, unless carefully controlled, there is serious danger of its detracting from the strength of the timber. There is also reason to believe that the seasoning it promotes, even in green timber, has been greatly overrated. In the case of seasoned and partially seasoned loblolly pine, experiments showed that the steam bath uniformly increased the moisture content of the wood. The following is one of a number of experiments which were made to test this point:

Ten 5-foot cross-arms were selected, each containing about 0.45 cubic foot. Three species of southern pine were represented—longleaf, shortleaf, and loblolly. The longleaf and loblolly arms were made up of both green and seasoned timber. All the arms were weighed immediately before treatment and placed in an experimental cylinder so arranged that all factors in the treatment could be carefully controlled. Live steam was then turned on and maintained for three hours at 20 pounds pressure. To assist in raising the temperature within the cylinder, steam was circulated through the heating coils arranged along the bottom. At the end of the steam bath the arms were quickly withdrawn and reweighed. The results are shown in Table 6.

TABLE 5.—*The effect of live steam upon the moisture content of pine cross arms.*

Kind of timber.	Grade.	Moisture condition.	Weight before steaming.	Weight after steaming.	Gain per arm.	Gain per cubic foot.
			Pounds.	*Pounds.*	*Pounds.*	*Pounds.*
Loblolly	Sap	Seasoned	20.0	22.5	2.5	5.5
Do	do	do	15.5	18.0	2.5	5.5
Do	do	do	18.0	20.0	2.0	4.4
Do	Heart	do	18.5	19.0	.5	1.1
Longleaf	do	do	18.0	19.5	1.5	3.3
Shortleaf	do	do	21.5	23.0	1.5	3.3
Longleaf	Intermediate	do	20.5	22.0	1.5	3.3
Do	do	Green	29.5	31.0	1.5	3.3
Loblolly	Heart	do	26.0	28.0	2.0	4.4
Do	Sap	do	23.0	24.5	1.5	3.3

In every case the steam bath increased the moisture content of the wood. This was true in the green arms as well as in those which had been seasoned to an approximately air-dry condition. The strength of partially seasoned timber is decreased up to a certain

point in proportion to the increase of the moisture content. As creosote retards the evaporation as well as the absorption of water, the original strength of the arms is not regained for long periods.

The principal benefit of the steam bath, at least with such species as loblolly pine, seems to consist in the thorough warming and expansion of the wood structure. The poor heat conductivity of wood, however, renders it doubtful whether more than the outer layers can be affected by steaming at safe temperatures and for ordinary lengths of time.

Moreover, the added moisture in the wood fibers tends to retard the absorption of the creosote. Probably the same objection can not be raised if aqueous solutions are used as preservatives, but with oils it is important that the fibers should be as nearly dry as possible. This view was substantiated by the result of the experimental treatments, which showed that the penetration in the steamed arms did not average as high as in the arms which had not been steamed. The durations of the steam baths varied from one to ten hours at 20 pounds pressure. The results were comparatively uniform, and showed little additional effect from the longer steaming periods. The above observations, however, do not necessarily apply to a wood of extremely resinous content, such as longleaf pine "fatwood." The effect of steam on such woods involves wholly different considerations.

It was also found that the preliminary vacuum could be abandoned without appreciably affecting the ease with which the timber absorbed the preservative. For timber as porous as air-dry loblolly pine the three or four hours which are usually required for the vacuum can be saved, with a considerable reduction in the expense of the treatments. Indeed, it is probable that the effects of the vacuum as a preparatory process have also been overestimated. However, even in the case of air-dry pine, the vacuum is desirable as furnishing an effective means for quickly drawing the preservative from the storage tanks to the treating cylinder.

Up to this point the experimental treatments had shown (1) that cross-arms of air-dry sapwood loblolly pine will quickly become thoroughly saturated with warm creosote (at about 125° to 140° F.) without the application of pressure; (2) that to saturate the heartwood it is necessary to apply pressure, and (3) that the steam bath and vacuum are unnecessary as preparatory processes.

A large saving in the time required for the treatment had been effected, but the more important point of bringing about an economy in the use of oil yet remained to be accomplished. This last object was fully attained by drawing a vacuum after the desired penetration had been secured.

EFFECT OF THE FINAL VACUUM.

During the process of seasoning most of the moisture in the cells and intercellular spaces in the wood is evaporated and is replaced by air. The preliminary vacuum, drawn only for a few minutes, chiefly for the purpose of filling the treating cylinder with the preservative, fails to reduce materially the amount of air in the wood structure. When the preservative enters the wood, either by its own penetrative power or by the application of pressure, it fails to replace entirely the air in the cells and intercellular spaces. If pressure is applied, the air becomes compressed, but can not all escape. When the oil is run out of the treating cylinder and a vacuum is applied the air in the wood structure not only tends to resume its original volume but by reason of the vacuum it exerts great expansive force, driving the superfluous oil out of the timber. This collects in the bottom of the treating tank, and after the vacuum has been continued for a sufficient period can be recovered by being blown back into the storage tanks.

Just as it is easier to penetrate sapwood than heartwood, the vacuum acts more sluggishly in the heartwood portions of the timber. Hence, although a greater amount of oil is forced into the sapwood, a proportionately greater amount is subsequently recovered, and the residue in the two different classes of wood tends to become fairly equal. By this method it is possible to continue the pressure until the heartwood has received the desired penetration without running the risk of leaving an unnecessary amount of oil in the more porous sapwood. The amount of oil that can be recovered by a final vacuum from pine timber is surprising. The treatments shown in Table 7 were made in the large commercial cylinders, 6 feet in diameter and 96 feet long. The amount of timber in a single load varied from 1,200 to 1,400 cubic feet.

TABLE 6.—*The effect of drawing a vacuum after impregnation.*

Class.	Pressure.	Absorption per cubic foot.	Length of vacuum at 23 inches.	Oil recovered.	
				Total.	Per cubic foot.
		Pounds.	*Hours.*	*Gallons.*	*Pounds.*
Sap	Force pumps not used	14.0	2	1,033	7.6
Intermediate	12 pounds for 12 minutes	13.6	2	875	6.6
Sap	Pressure applied for 18 minutes reaching a maximum of 16 pounds.	16.0	1	1,130	8.0
Heart	Pressure applied for 35 minutes reaching a maximum of 70 pounds.	15.0	1½	358	3.2
Intermediate	15 pounds for 4 minutes	15.0	¼	600	5.1
Sap	Pumps worked for about 8 minutes, but no pressure registered.	25.0	¾	1,302	10.7
Do	8 pounds for not more than 3 minutes.	21.0	1	1,659	11.5

If the vacuum had been continued longer in all of the runs it is probable that even a greater amount of oil could have been extracted. The treated wood appeared dry on splitting. The cells contained little free oil, but the walls were thoroughly coated.

It is believed, therefore, that the method of drawing a vacuum after impregnation accomplishes the desired results. The heartwood, in most cases, received an absolute impregnation without the absorption of large quantities of oil. In some cases the penetration extended in the heartwood for about an inch and a half from the sides; the interior was not wholly discolored by the oil, but showed the presence of a small amount of creosote by dark spots and flecks appearing along the pores. Such a penetration is believed to be ample for timber of this character, where decay alone, and not mechanical abrasion, is to be guarded against.

The amount of oil that should be injected before drawing the vacuum depends almost wholly upon the relative amounts of heartwood and sapwood. If the timber is composed almost wholly of heartwood much less need be injected than if sapwood is present. The point of importance is not the amount of oil the timber is made to absorb, but to apply enough pressure to force the oil into the heartwood portions. Hence, if no heartwood is present, little or no pressure need be applied.

The amount of oil left in the timber must depend upon whether it is composed of heartwood or sapwood and upon the individual opinion of the owner. Until more is known of the changes which creosote undergoes in wood exposed to the full force of the sun and wind, it is recommended that 10 pounds of oil per cubic foot be allowed to remain in the sap class of arms, 8 pounds in the intermediate class, and 6 pounds in the heart class. It may be perfectly safe to reduce the oil in all classes of timbers to about 6 or 8 pounds per cubic foot, or even lower. Certain of the most abundant constituents of creosote evaporate at summer temperature on exposure to the air; hence it is prudent to obtain creosotes which have the smallest proportion of volatile oils. It is very desirable that experiments should be undertaken to ascertain definitely what changes take place in treated wood. Preliminary analyses of treated sections of several years' exposure are suggestive, and indicate a need for more complete results.

EXPERIMENTS WITH GREEN TIMBER.

In the foregoing experiments the timber weighed about 31.5 pounds per cross-arm, or between 34 and 35 pounds per cubic foot, and, if possible, the wood should always be allowed to reach this or a less weight before treatment. In order to test the impregnation of green wood, a few cross-arms of green loblolly pine were weighed and

treated. An oil pressure of 20 pounds was applied for fifteen minutes. The pressure was then increased to 40 pounds and held at that point for fifteen minutes. The superfluous oil was then blown back into the storage tank, and a vacuum of about 25 inches was drawn for half an hour. The green timber showed an average gain of only 2.2 pounds per cubic foot as compared with 12.6 pounds in dry sapwood in the same load. But by splitting the green arms it was found that a good penetration had been received. The oil had penetrated into the wood for several inches from the ends and from the insulator pin holes, and even along the sides a fairly good penetration had been obtained. The color of the treated wood was much lighter than in the dry arms, on account of the large amount of water with which the preservative was mixed.

This experiment by no means indicates that seasoning is unnecessary. The comparative lack of strength of green timber, as well as its tendency to check and split, and so to expose the unprotected wood, make thorough air seasoning imperative. And it is not known what the effect of so large an amount of water upon the permanency of the creosote in the wood will be. That such thoroughly moistened fibers can become completely saturated with creosote is doubtful. The results are of value, however, in indicating that, when necessary because of an emergency, partially seasoned timber can be used.

THE SAVING BY THE PROCESS RECOMMENDED.

The adoption of the process recommended will effect a saving both in the amount of oil required for thorough impregnation of the timber and in the time of treatment. A saving of even 2 pounds of oil per cubic foot of timber in an ordinary commercial load of about 1,400 cubic feet means a very considerable reduction in the cost of treatment. In many cases a much greater quantity can be saved.

The omission of the steam bath brings about a decided saving in fuel; of considerably more importance is the saving in time. To treat a load of cross-arms in accordance with the specifications in common use requires from six to eight hours. Under the specification recommended in this report the time will be reduced to less than two hours, and when it is remembered that the number of the quickly treated sapwood runs will greatly exceed that of the slower heartwood runs, it is evident that the average time of treatment can probably be still further reduced. The capacity of a plant, and therefore, to a lesser extent, its profits, depends primarily upon the daily number of runs.

GRADING.

PERMANENT BASIS FOR GRADES.

At the beginning of the study the basis for the heartwood and sapwood classes was chosen somewhat arbitrarily. It provided that all arms containing at least 75 per cent of heartwood should be separated into Class A and those with at least 75 per cent sapwood into Class B. Class C, or the intermediate arms, were to contain 75 per cent of neither heartwood nor sapwood. The results of the later treatments have proved this basis correct, and it is recommended that it be followed in commercial practice.

GRADING AT THE TREATING YARD.

When the carloads of arms for the experiments arrived at the treating plant they were unloaded and piled on the yard to season. The grading was done as the arms were unloaded from the car. A force of about six men was employed for each car. Each arm had to be marked individually with crayon, to be later restamped with iron stencils, and this necessarily delayed the unloading to a greater extent than would have been the case had it been necessary merely to grade the arms and not to mark them. Even with this handicap, however, the unloading was almost as quickly accomplished as in ordinary commercial practice without grading. It is important to note that even the unskilled labor employed in unloading and piling the arms soon became fairly expert in quickly deciding into which class each arm belonged, and it soon became sufficient merely to check the judgment of the laborers. The present commercial custom requires the presence of an inspector at the unloading of each carload of lumber, in order to pass upon the soundness and other specified qualities of the timber. This in itself necessitates the individual examination of each arm as it is removed from the car; no additional time is required to indicate to the laborers in which of the three piles the particular arm is to be placed. The cost of grading, therefore, under most circumstances is negligible.

GRADING AT THE MILL.

If conditions make it advisable to avoid the grading at the treating yards—and under most circumstances this will probably be the case—an excellent plan is to have the arms graded at the mill and shipped to the treating yard in separate cars.

In many localities the cross-arm mill is located on the railroad, where shipping is comparatively quick and inexpensive. The actual felling of the timber is carried on within a wide radius of the surrounding country. The logs are hauled to small portable sawmills, which constantly follow the base of supply. There they are sawed into timber of rather rough dimensions, which is next carried on

wagons to the cross-arm mill. The next step is to plane and edge the timber to the exact dimensions specified for the arms. The timber is then passed on to the boring machine, where the bolt, pin, and brace holes are bored, and finally the upper edges are rounded off and the arm is ready for shipment. During this process of manufacture each piece of timber is carefully examined by an inspector, who separates the arms into different grades—firsts, seconds, and culls.

To one as experienced in handling lumber as this inspector must necessarily be it is only the work of an instant to grade the arms into the additional classes, depending upon the relative amounts of heartwood and sapwood. His judgment can be indicated by a slight crayon mark. When the arm is finally removed from the finishing machine this mark will indicate into which car or in which pile the arm is to be placed. Then the graded arms are shipped to the treating mill in separate cars, and the work of the treating plant inspector, so far as the grading is concerned, is reduced merely to passing upon the judgment of the inspector at the mill. If the arms have reached an air-dry condition they can then be unloaded directly from the railroad cars to the cylinder buggies; otherwise they are piled in the yard to season.

SEASONING AT THE MILL.

Whether or not the arms should be seasoned at the treating yard or at the mill before shipment depends entirely upon local conditions. If convenient arrangements can be made at the mill, they should by all means be seasoned before shipment. This results in lessening the handling of the arms at the treating yard, and in considerably reducing the freight charges. A carload of green arms frequently weighs from 55,000 to 60,000 pounds. A loss in weight of 40 per cent reduces this weight to not more than 36,000 pounds, a saving of the freight charges on from 22,000 to 24,000 pounds of lumber. Even for comparatively short hauls this saving is decidedly more than sufficient to defray the slight extra cost of grading and seasoning. In most cases no extra expense is entailed in grading the arms; 50 cents per carload is believed to be a liberal average estimate. There is no extra cost to season the arms other than that entailed by one extra handling of the timber and by holding it for a comparatively few weeks. Often both these items of expense are already present because, even in the ordinary practice, arms will arrive at the treating plant more rapidly than they can be treated, and piling in the yard is necessary.

SUMMARY.

The results of the entire study are summarized in the following recommendations:

1. During the process of manufacturing the arms they should be graded into three classes: Arms that contain at least 75 per cent of

heartwood; arms that contain at least 75 per cent of sapwood, and arms that occupy an intermediate position.

2. The arms should next be piled in the seasoning yard until they have approached an air-dry condition. The form of the pile should be 20 by 20, with the two end and middle arms turned with the wider sides vertical. In winter the piles should be covered with a roofing of plank to protect the arms from snow and rain. The seasoning yard should be so situated as to afford full access to the winds, and avenues at least 4 feet wide should be left between the piles so as to allow currents of air to flow freely on all sides of the timber.

3. If it has been possible to season the timber at the mill, each class or grade should, when the arms have approached an air-dry condition, be loaded in separate cars and shipped to the treating plant, where they can be unloaded directly on the cylinder buggies. During this unloading the inspector will have a chance to check up the inspection and grading at the mill.

4. Each class of arms should be treated separately. The usual preliminary bath of live steam should be omitted. A vacuum should be applied only sufficient to draw the oil from the storage tanks into the treating cylinder. If the arms belong to the sapwood class, no pressure is necessary in most cases, but care should be taken to apply sufficient pressure, if necessary, to penetrate the heartwood portions of the arms. The exact amount of oil absorbed by the timber should be carefully noted. When the impregnation has been completed the surplus oil should be blown back into the storage tanks and a vacuum drawn in the treating cylinder. From time to time the oil which is forced out of the timber by the expansion of the air during the vacuum, and which collects in the bottom of the cylinder, is blown back into the storage tanks. The vacuum should be continued until only the desired amount of oil is left in the timber. It is recommended that the arms of Class A (heartwood) should finally contain about 6 pounds per cubic foot; the arms of Class C (intermediate) about 8 pounds per cubic foot, and the Class B arms (sapwood) about 10 pounds per cubic foot.

The cylinder doors are then opened, and the treatment is complete. The total length of the average treatment will probably fall considerably under two hours.

Approved:

JAMES WILSON,
Secretary of Agriculture.

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